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(54) **RE-CIRCULATING FLUID DELIVERY SYSTEMS**

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(52) **U.S. Cl.** **347/89**; 347/92

(58) **Field of Search** 347/85, 86, 87, 347/89, 92, 93

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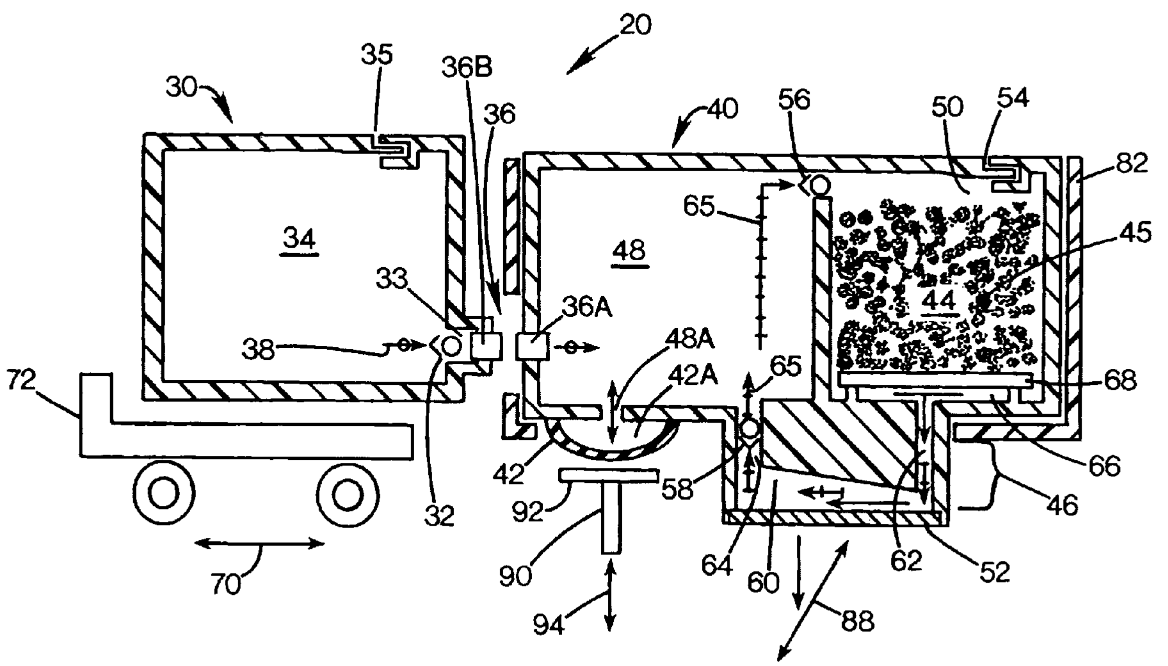
(57) **ABSTRACT**

A re-circulating fluid delivery system includes an air-fluid separator structure, a fluid plenum in fluid communication with the separator structure, and a free fluid reservoir. A fluid re-circulation path fluidically couples the separator structure, the fluid plenum and the free fluid reservoir. A pump structure re-circulates fluid through the re-circulation path during a pump mode, wherein air bubbles may be separated from re-circulated fluid.

23 Claims, 5 Drawing Sheets



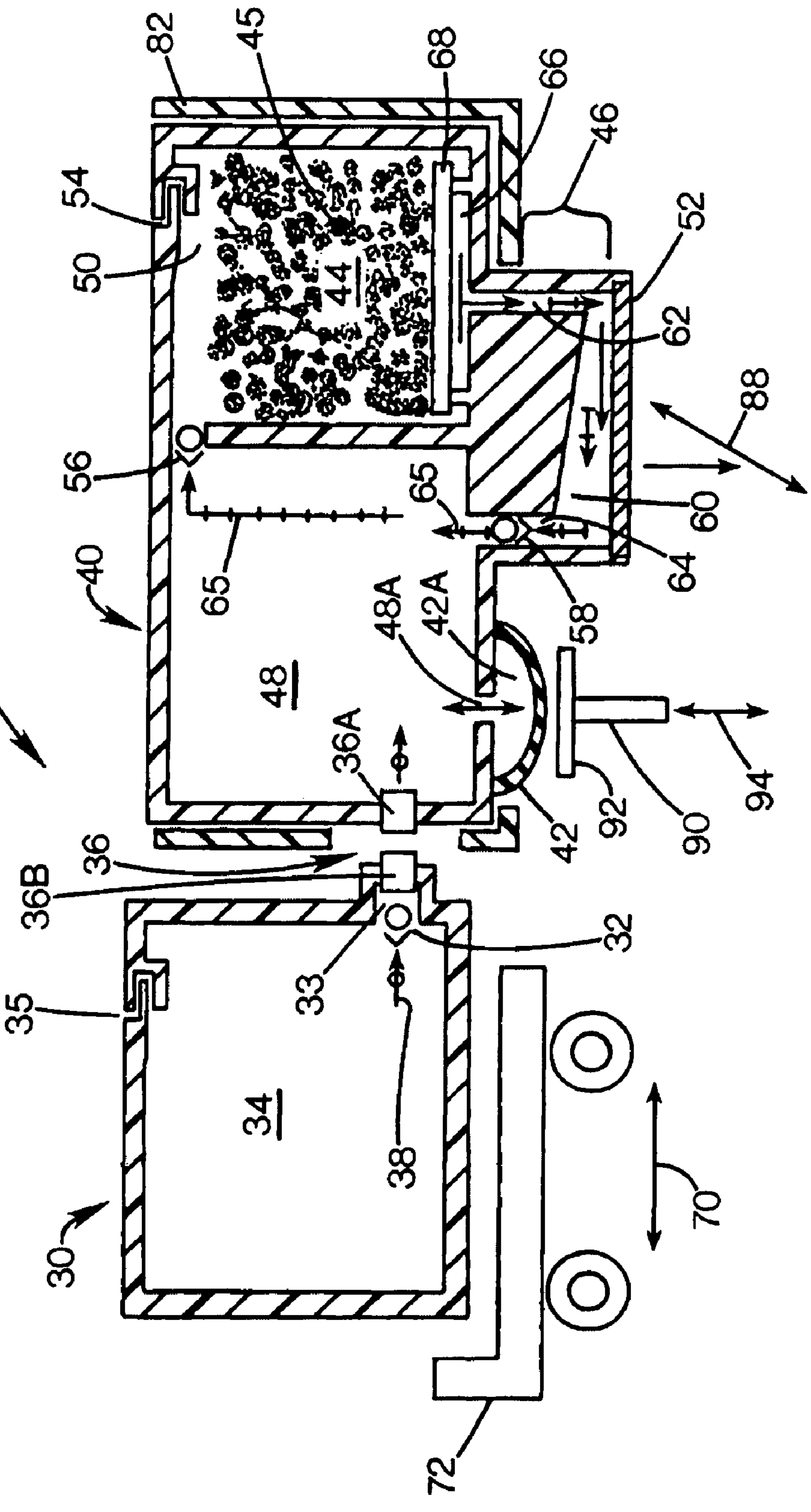

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FIG. 1

FIG. 2A

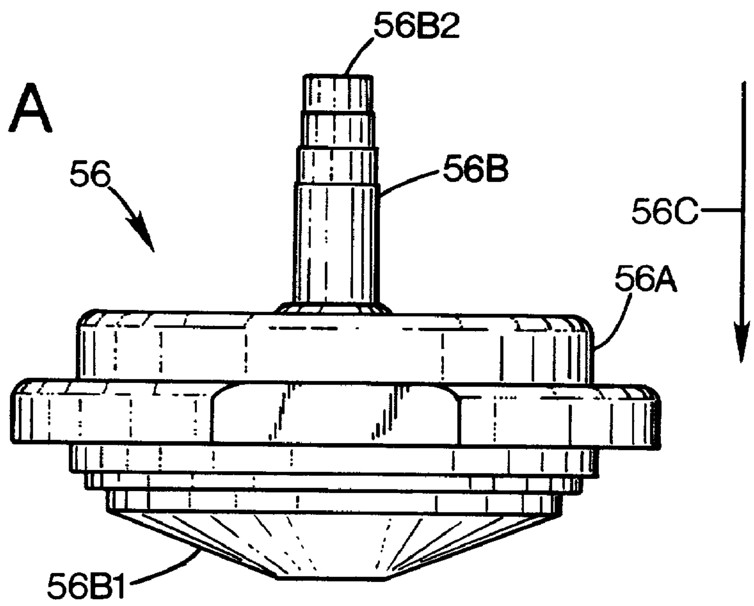
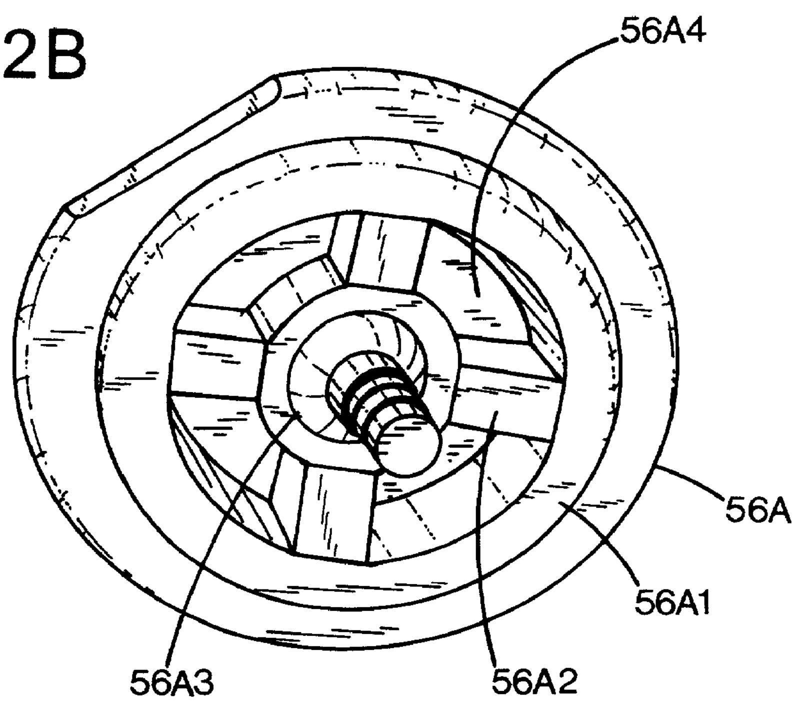


FIG. 2B



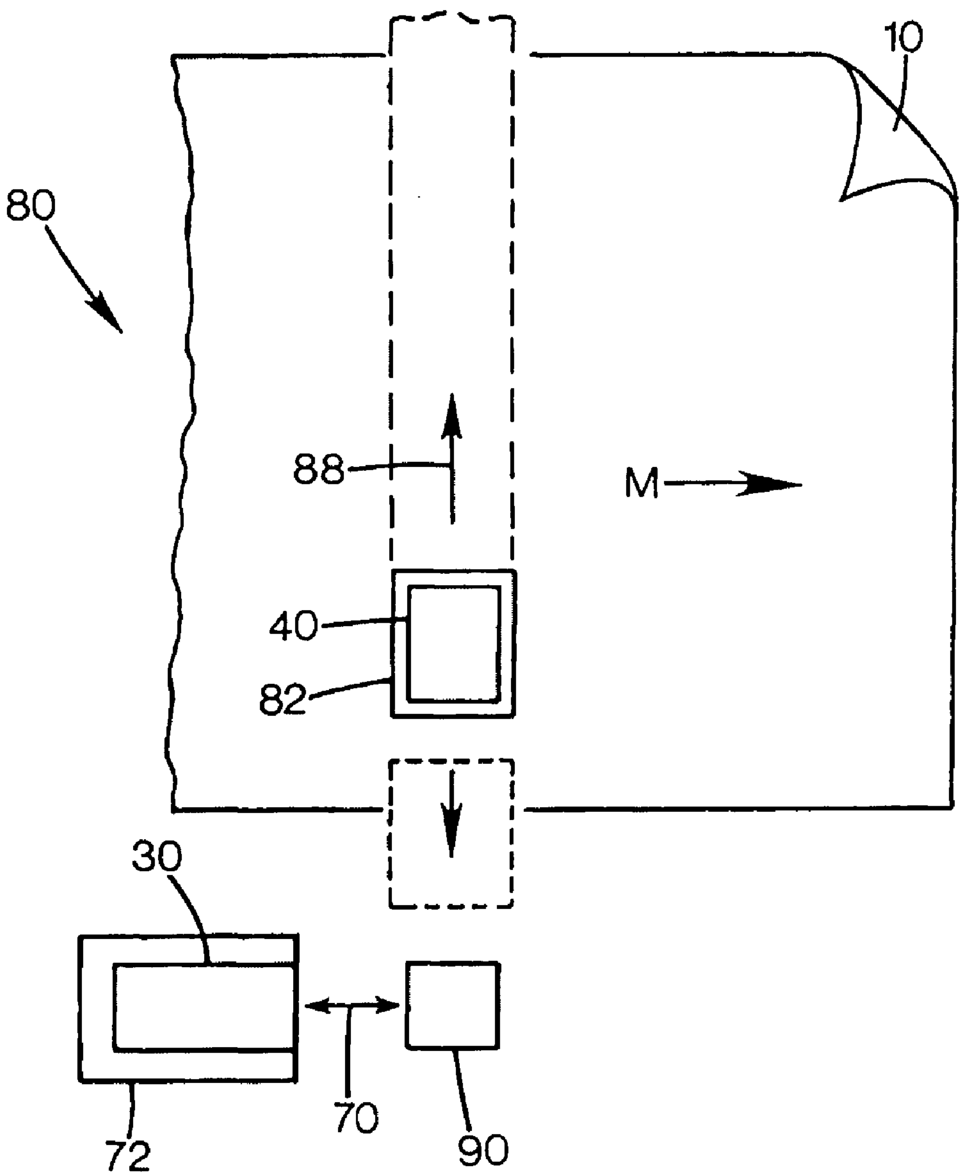


FIG. 3

FIG. 4

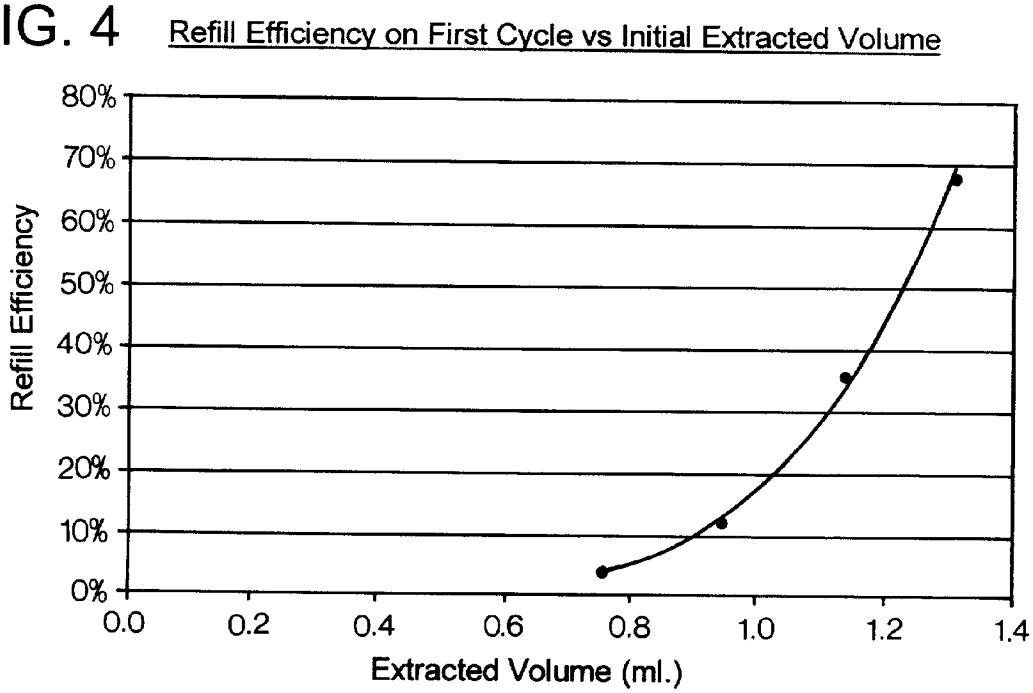
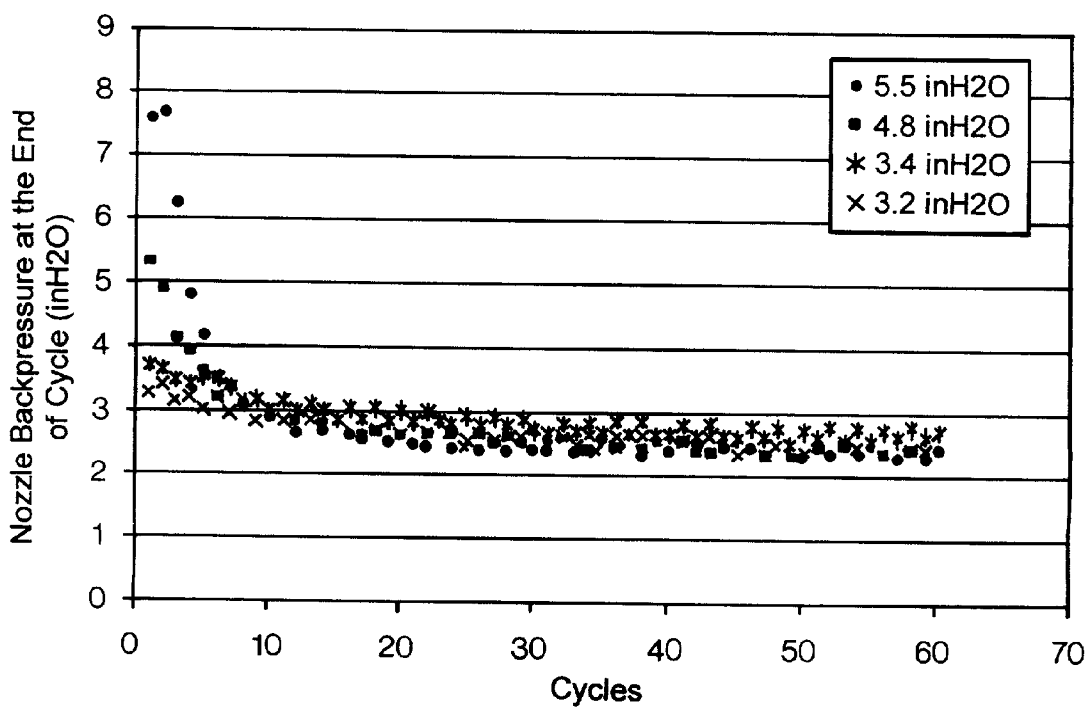

Refill Efficiency on First Cycle vs Initial Extracted Volume
80%
70%
60%
50%
40%
30%
20%
10%
0%
Refill Efficiency
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Extracted Volume (ml.)

FIG. 5


9
8
7
6
5
4
3
2
1
0
Nozzle Backpressure at the End of Cycle (inH2O)
0
10
20
30
40
50
60
70
Cycles
5.5 inH2O
4.8 inH2O
3.4 inH2O
3.2 inH2O

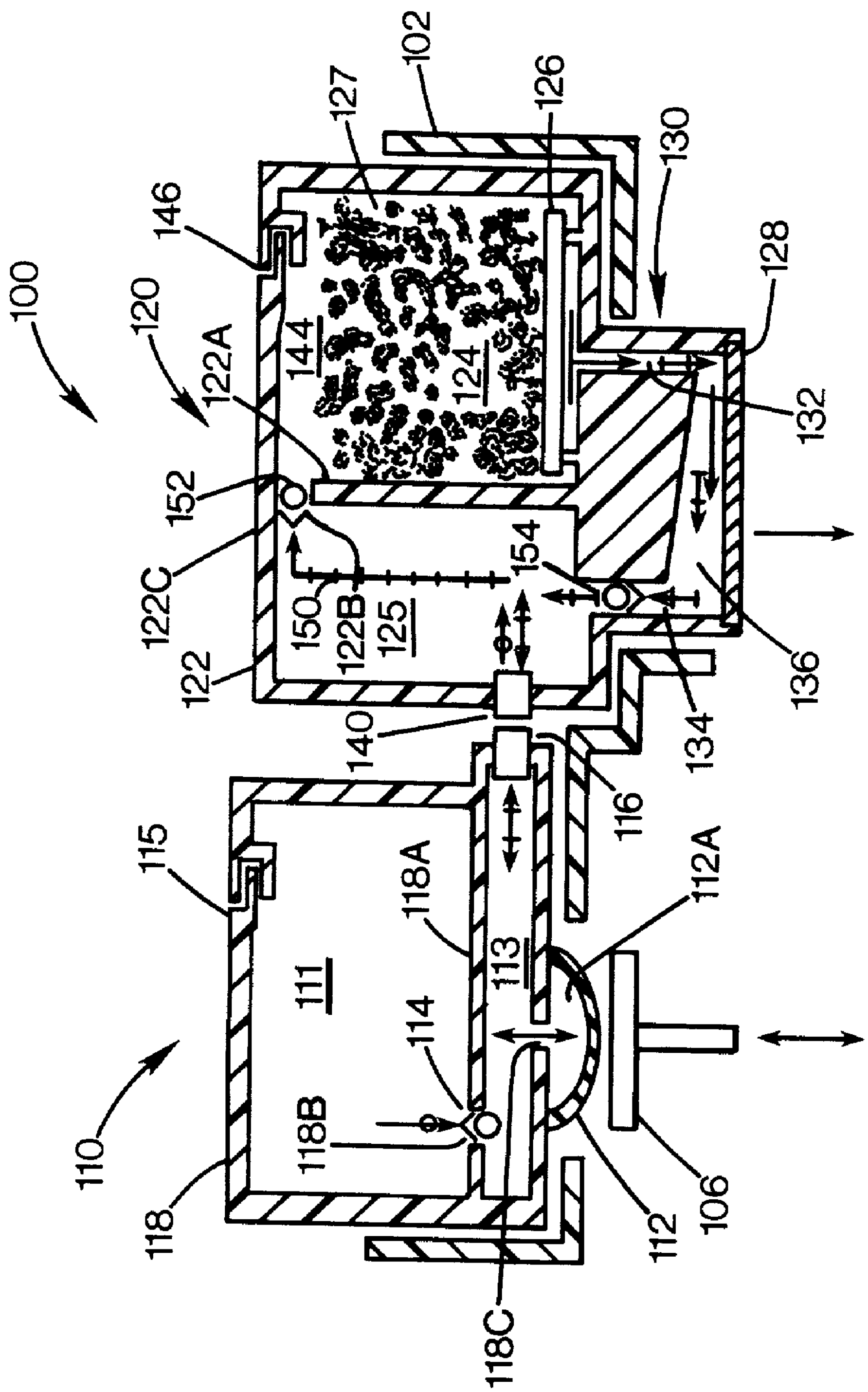

100
120
122A
144
146
127
102
126
130
128
132
124
152
122C
150
122B
125
122
154
136
134
140
116
115
111
118A
113
112A
114
118B
110
118
106
112
118C

FIG. 6

RE-CIRCULATING FLUID DELIVERY SYSTEMS

BACKGROUND OF THE DISCLOSURE

One exemplary application to which the present invention has utility is that of printing systems. Fluid delivery systems are in common use for delivering liquid ink in printing systems, such as ink-jet printing systems. One type of fluid delivery system is the re-circulating system type. Re-circulating fluid delivery systems are inherently air tolerant. These types of systems move air and ink from the print head region of a print cartridge, separate the air from the ink using either a foam block or by gravity, and circulate the ink back to the print head. The driving force of the re-circulation is generally the same as that to deliver ink.

One type of known re-circulating fluid delivery system employs tubes through which the fluid is delivered. Tubes add significant cost to the fluid delivery system, and increase the amount of force required to drive the print head back and forth during printing. These tube-based systems allow fluid to flow bi-directionally, that is, from the fluid supply to the print head and from the print head to the fluid supply. The system refills the cartridge, with fluid flowing from the supply to the print head. Then, to obtain the correct pressure, excess fluid is caused to flow back from the print head to the fluid supply. The system can overshoot its operating pressure, or set point, and is therefore at risk for overfilling. The set point is negative pressure, referred to as back pressure. If the cartridge were overfilled, poor print quality or drooling out of the nozzles could result.

SUMMARY OF THE DISCLOSURE

A re-circulating fluid delivery system is described. The system includes an air-fluid separator structure, an air vent region, a fluid plenum in fluid communication with the separator structure, and a free fluid reservoir. A fluid re-circulation path fluidically couples the separator structure, the fluid plenum and the free fluid reservoir. A pump structure re-circulates fluid through the re-circulation path during a pump mode, wherein air bubbles may be separated from re-circulated fluid and vented to atmosphere from the air vent region.

BRIEF DESCRIPTION OF THE DRAWING

These and other features and advantages of the present invention will become more apparent from the following detailed description of an exemplary embodiment thereof, as illustrated in the accompanying drawings, in which:

FIG. **1** is a schematic illustration of an embodiment of a re-circulating fluid delivery system in accordance with the invention.

FIGS. **2**A and **2**B are side and isometric end views of an exemplary check valve structure usable in the system of FIG. **1**.

FIG. **3** is a schematic diagram of a printer system employing the fluid delivery system of FIG. **1**.

FIG. **4** graphically illustrates an exemplary refill efficiency for a prototype of the system of FIG. **1**.

FIG. **5** illustrates the refill process over a number of cycles, plotting for an exemplary embodiment nozzle backpressure at the end of a cycle as a function of the cycle count.

FIG. **6** is a schematic illustration of an alternate embodiment of a fluid delivery system in accordance with the invention.

DETAILED DESCRIPTION OF THE DISCLOSURE

An exemplary embodiment of a re-circulating fluid delivery system **20** in accordance with aspects of the invention is schematically illustrated in FIG. **1**. The system comprises a fluid supply **30**, a print cartridge **40** incorporating a pump structure **42** and an air-fluid separator **44**. A fluidic interconnect **36** provides a fluid path between the fluid supply and the print cartridge. The air-fluid separator includes a body **45** of some form of capillary material, such as bonded-polyester fiber foam, polyurethane foam or glass beads. In this embodiment, the pump structure **42** is a pump diaphragm that includes an elastomer material formed into a convex shape with an internal spring that rebounds the pump volume after the elastomer is pushed in by an external driving force.

Exemplary fluid interconnect structures suitable for the purpose as **36**A, **36**B are known, such as needle-septum interconnects, e.g. as described in U.S. Pat. No. 5,815,182.

The fluid supply **30** can include a volume **34** of free fluid within a rigid container having a vent **35**, or in a flaccid bag. If a vent is used, it is open during use, but sealed during shipping to prevent leakage. In either case, in this exemplary embodiment, the fluid supply has a high-cracking pressure check valve **32** at its outlet port **33**. The outlet port also has a fluid interconnect structure **36**B, for mating with a corresponding fluid interconnect structure **36**A on the print cartridge **40**. Exemplary cracking pressure for the check valve suitable for the purpose in an exemplary embodiment are in the range of 12 to 20 inches of water.

The print cartridge **40** includes, in addition to the capillary material/air-fluid separator **44**, a standpipe area **46**, a free fluid chamber **48**, an air vent region **50** and a printhead **52** which ejects droplets of fluid through a nozzle array. In this embodiment, the fluid is a liquid ink during normal printing operations. The fluid can alternatively be a cleaning fluid, a benign shipping fluid, a make-up fluid or the like.

The printhead **52** can be any of a variety of types of fluid ejection structures, e.g. a thermal inkjet printhead or a piezoelectric printhead.

In the exemplary embodiment of FIG. **1**, the separator **44** also provides back pressure to the printhead **52**. The capillary material in an exemplary embodiment is selected to provide a static back pressure in the range of 2 to 6 inches of water. The air vent region **50** of the air fluid separator **44** is a small volume of humid air above the capillary material **45** that is vented to atmosphere via a labyrinth vent **54**.

The standpipe region **46** includes a fluid plenum **60** in fluid communication with the printhead **52**, supplied with fluid through channel **62** from open region **66** below a filter **68** separating the capillary material **45** from region **66**. The filter **68** can be fabricated, e.g, from a fine mesh screen, e.g. with a 6 micron nominal opening size in an exemplary embodiment. The filter is characterized by a high bubble pressure characteristic, which is sufficient to prevent passage of air bubbles under conditions experienced by the print cartridge during shipping, operation or storage.

The print cartridge **40** includes two one-way check valves **56**, **58**. Check valve **56** is disposed in a fluid path between the top of the free fluid chamber **48** and the air vent region **50**, allowing air and fluid to flow from the chamber **48** into separator **44** and air vent region **50** when the cracking pressure of the valve is exceeded. Fluid flow from the region **50** into chamber **48** is prevented by the check valve **56**. Check valve **58** is disposed in a fluid channel **64** between the standpipe region **46** and the free fluid chamber **48**, permitting fluid to flow from the standpipe region into the free fluid chamber **48** when the cracking pressure of the valve **58** is exceeded, while preventing fluid flow in the opposite direction from chamber **48** to plenum **60**. In an exemplary embodiment, the valves **56**, **58** have a cracking pressure in the range of 2 to 3 inches of water, and in one exemplary embodiment, a cracking pressure of 3.25 inches of water. For this embodiment, the plenum static pressure is on the order of −2 to −6 inches of water, and while printing a plenum dynamic pressure in the range of −2 to −12 inches of water. While pumping, the plenum pressure could be as high as −25 to −30 inches of water, or a negative pressure below a threshold at which air bubbles would be ingested through the print head nozzles, since print quality is not an issue during pumping.

There are many types of check valve structures which can be employed to perform the function of the check valves **56**, **58** and **32** for the system. One exemplary type of valve structure is illustrated in FIGS. **2A–2B**. This valve structure is illustrated as check valve **58**, but is also usable for the other check valves as well. The valve structure is an umbrella valve, having a valve seat structure **56**A which has an outer frame **56A1** with ribs **56A2** radiating from a hub **56A3**, the ribs separated by openings **56A4**. An umbrella structure **56B** includes umbrella **56B1** integrally formed with post **56B2** which is positioned through the hub of the seat structure. The seat structure is fabricated of a rigid plastic material such as PPS, MABS, ABS, PET or LCP; the umbrella structure **56**B is fabricated of an elastomeric material such as silicone, EPDM, or an thermoplastic elastomer, to permit the deflection of the umbrella away from the rim of the seat structure in response to fluid pressure exceeding the break pressure, allowing fluid to flow through the valve in the direction of arrow **56**C (FIG. **2**A).

In an exemplary embodiment, the print cartridge **40** is mounted on a traversing carriage **82** of a printer **80**, and the carriage is driven along a swath axis **88** during printing operations, as depicted schematically in FIG. **3**. The swath axis is substantially perpendicular to the motion of print media **10** through the printer, as indicated by arrow M. The fluid supply **30** is mounted on a printer supply shuttle **72** at a supply station. The shuttle can be driven to move the fluid supply along a supply axis **70** which is transverse to the swath axis between a supply rest position (shown in FIG. **1**) and an engaged position where the fluid interconnect **36**B is mated with corresponding fluid interconnect **36**A of the print cartridge. Of course, other arrangements could alternatively be employed, e.g., the fluid interconnect axis could be parallel to the carriage axis.

At system start-up, the carriage **82** is moved along the swath axis **88** to position the print cartridge at the supply station. Then, a printer shuttle mechanism linearly actuates the shuttle **72** to move the fluid supply **30** along axis **70** toward the print cartridge to temporarily connect to the print cartridge **40** through the fluid interconnect structures **36**A, **36**B. The print cartridge **40** is assumed to be in a fluid-depleted state, requiring fluid so that the maximum amount of pages can be printed before the next refill. The printer then actuates a mechanism **90** to drive the pump on the print cartridge, causing fluid to flow from the fluid supply to the print cartridge. The mechanism **90** can include an actuator **92** which is reciprocated along actuator axis **94** (FIG. **1**) to contact and compress the pump diaphragm **42** in repeated cycles of the actuator operation. This collapses the pump chamber **42**A, forcing fluid in the chamber through opening **48**A into the free fluid chamber **48**. This in turn forces fluid and air through check valve **56** into the separator **44**. Other types of pump structures could alternatively be employed, e.g, piston or electro-mechanical structures.

While fluid is being pumped into the free fluid chamber **48** in the print cartridge, a small amount of fluid is also flowing from the plenum **60** through channel **64** and check valve **58** along the recirculation path indicated by arrows **65** of the print cartridge into the free fluid chamber **48**.

The dynamic flow loss through the capillary material **45** is quite high during the first one or two cycles of pump operation, since the capillary material is highly depleted at the initial stage of refilling and the filter **68** has a high bubble pressure characteristic preventing flow of air bubbles through the filter under normal operating, storage and pumping conditions experienced by the print cartridge. Therefore flow through the air-fluid separator **44** is not the most preferred path for fluid flow. Less flow resistance exists through the fluid supply path **38**, i.e. from the supply **30** through interconnect **36**, and fluid is drawn in from the supply **30** initially at about 50%–70% of each pump volume, i.e. the volume of pump chamber **42**A, in an exemplary embodiment. The amount of fluid drawn in from the supply **30** during refill divided by the pump volume is referred to as the refill efficiency. The refill efficiency drops from about 70%–50% on the first one or two pump cycles very quickly as the print cartridge refills. FIG. **4** graphically illustrates an exemplary refill efficiency for a prototype of the system **20**.

As the refill efficiency drops off, the amount of fluid recirculating through path **65** increases. As the print cartridge **40** takes on more fluid, the capillary material **45** becomes more saturated and the dynamic flow loss through the capillary material and the filter **68** decreases, making it easier to draw fluid from the standpipe region. The system therefore takes on smaller amounts of fluid from the fluid supply **30** as it approaches its equilibrium, or set point. The set point is the back pressure that is optimal for printing, and in an exemplary embodiment it is also the same back pressure in the standpipe at which full re-circulation takes place, i.e., when the refill efficiency is 0%. At this set point, the pump volume is replenished completely via the re-circulation path **65**, instead of from the fluid supply **30**.

FIG. **5** illustrates an exemplary refill process over a number of cycles, plotting for an exemplary embodiment nozzle back pressure at the end of a cycle as a function of the cycle count, with one cycle consisting of a pump actuation in and subsequent rebound. FIG. **5** shows the inherent stability of the system of FIG. **1**. If, as in prior solutions, the system overfilled the print cartridge and then withdrew excess fluid back into the supply, then the back pressure would drop down below the set point of 2.4 inches of water and then return to set point some cycles later. In this embodiment, the system reaches its set point without overfilling.

After a complete fill, the print cartridge **40** is ready to print. The size of the capillary material in the print cartridge determines the number of pages that can be printed before refill is required. The number of drops per page will vary the number of pages possible.

During printing, air that is generated due to outgassing of the fluid will accumulate in the small standpipe fluid channels **62**, **64** (FIG. **1**). Without connecting to the fluid supply **30**, an air purging routine can be performed on the print cartridge **40** to purge air from the channels **62**, **64**. The fluidic connection at interconnect structure **36**A is normally closed, and opens only upon connection to the fluid supply **30**. The carriage **82** is moved to the supply station, and, with the fluid supply **30** still in its rest position out of engagement with the print cartridge, the pump mechanism **90** is activated. Any air in the standpipe region **46** can be circulated through the recirculation path **65** and separated in the air-fluid separator **44** without connecting the print cartridge to the fluid supply.

During long periods of idle time, or between print jobs, the printer can purge air from the printhead without having to actuate the fluid interconnects or the supply shuttle if refill is not required. This can reduce the wear of the fluid interconnects and supply shuttle components, and save time for the servicing routine, since the supply shuttle would not have to be activated.

An alternate embodiment of a fluid delivery system **100** is illustrated in FIG. **6**. The fluid supply/print head arrangement is commonly referred to as a "snapper" system, since the supply has a fluid interconnect which snaps together with a fluid interconnect on the print head, and remains snapped together during printing, the printer carriage **102** holding both the print cartridge and the fluid supply. In this embodiment, the pump is still located "on axis," i.e. on the traversing carriage **102**, but is fabricated as part of the fluid supply. This increases the reliability of the pump system, since the diaphragm is replaced each time a new fluid supply is installed.

The system **100** shown in schematic form in FIG. **6** includes the fluid supply **110** which holds a supply of fluid in an internal fluid reservoir **111**. The reservoir **111** is vented to the atmosphere through a labyrinth vent **115**, which is open during use, but sealing during shipping to prevent leakage. The supply housing **118** includes an internal wall structure **118**A, separating reservoir **111** from a free fluid chamber **113**. The wall structure **118**A has an opening **118**B formed therein, with a check valve **114** disposed in the opening to prevent fluid from flowing from chamber **113** into reservoir **111**.

The fluid supply **110** has a pump structure **112** attached to the housing **118**, in fluid communication with the fluid chamber **113**. In an exemplary embodiment, the pump structure **112** is a diaphragm pump structure, although other types of fluid pumping structures could alternatively be employed, such as a spring-loaded piston pump. The pump diaphragm **112** defines a pump chamber **112**A which communicates with chamber **113** through port **118**C, which allows bi-directional fluid flow between the chambers **113**, **112**A.

The fluid supply **110** includes a fluid interconnect structure **116** for engaging a corresponding interconnect structure **140** on the print cartridge **120**. Exemplary fluid interconnect structures suitable for the purpose include needle/septum structures, such as those described in U.S. Pat. No. 5,815,182.

The print cartridge **120** includes a housing **122** with an internal wall structure **122**A, forming a free fluid chamber **125** separated by wall structure **122**A from reservoir **127**, with a check valve **152** disposed at an opening **122**B in the wall structure **122**A adjacent the top wall **122**C. A body **124** of capillary material is disposed in reservoir **127**, forming an air-fluid separator.

The print cartridge further includes a standpipe area **130**, an air vent region **144** and a printhead **128** which ejects droplets of fluid through a nozzle array. In the exemplary embodiment of FIG. **6**, the separator **124** also provides back pressure to the printhead. The air vent region **144** is a small volume of humid air above the separator **124** that is vented to atmosphere via a labyrinth vent **146**.

The standpipe region **130** includes fluid flow channels **132**, **134** leading to a fluid plenum **136** above the printhead **128**. Channel **132** communicates with the separator **124** through a filter **126**. Channel **134** communicates with free fluid chamber **125**. A check valve **154** is positioned in the channel **134**.

Check valve **152** permits one-way fluid flow from the free fluid chamber **125** to the separator **124** when the break pressure of the valve is exceeded, preventing fluid flow in the opposite direction. Check valve **154** permits one-way fluid flow in channel **134** between the plenum **136** and the free fluid chamber **125** when the break pressure of the valve is exceeded, preventing fluid flow in the opposite direction.

A recirculation path **150** allows fluid to be recirculated, through action of the pump **112**, through the free fluid chamber **125** and valve **152** to the capillary material **124**, the standpipe channel **132**, plenum **136**, channel **134**, through valve **154** back to the free fluid chamber **125**, and between the chamber **113** of the fluid supply through interconnects **116**, **140**. The pump **112** actuation occurs in one exemplary embodiment by moving the carriage to a service station at which the actuator **106** is disposed, and then reciprocating the actuator **106** by a pump actuator mechanism to repetitively cycle the pump diaphragm.

The check valves **152**, **154** have break pressures in an exemplary embodiment in the range of 2 to 4 inches of water. The supply check valve **114** has a break pressure in an exemplary embodiment in a range of 12 to 20 inches of water, and is high enough to account for flow losses through the fluid interconnect. The break pressures are balanced with the dynamic flow losses through the recirculation path and capillary material.

The system **100** illustrated in FIG. **6** provides an on-axis fluid supply with an air tolerant re-circulation system. An air-fluid separator is located on-axis with the fluid supply, allowing air tolerance without requiring large amounts of fluid to be wasted for air purging. Moreover, incorporating the pump into the fluid supply, as in the embodiment of FIG. **6**, allows a more reliable pump, since the pump diaphragm is replaced with the fluid supply. The pump material properties may change over time in contact with the fluid due to solvent absorption or creep. Since the pump will undergo many cycles, fatigue may cause damage. If the pump diaphragm is replaced periodically, the required material life is much shorter and may allow reduced cost over a permanent pump.

It is understood that the above-described embodiments are merely illustrative of the possible specific embodiments which may represent principles of the present invention. Other arrangements may readily be devised in accordance with these principles by those skilled in the art without departing from the scope and spirit of the invention.

What is claimed is:

1. A re-circulating fluid delivery system, comprising:

a print cartridge housing structure;

an air-fluid separator structure disposed in said housing structure, the separator structure including an air vent;

a fluid plenum in fluid communication with said separator structure;

a printhead mounted to said housing structure and in fluid communication with said plenum;

a free fluid reservoir disposed in said housing structure;

a fluid re-circulation path entirely within said housing structure fluidically coupling said separator structure, said fluid plenum and said free fluid reservoir; and

a pump structure for re-circulating fluid through said re-circulation path during a pump mode, wherein air bubbles may be separated from re-circulated fluid and vented to atmosphere from said air vent region.

2. The system of claim 1, wherein said fluid re-circulation path has disposed therein at least one check valve permitting fluid flow in a re-circulation direction.

3. The system of claim 1, wherein said pump structure is mounted to said housing structure.

4. The system of claim 1 further comprising a fluid supply external to said housing structure and a fluid interconnect structure for removable connection of the fluid supply to the free fluid reservoir.

5. The system of claim 4, wherein said fluid supply and said free fluid reservoir are intermittently connectable during a refill mode, and are disconnected during printing operations performed by said printhead.

6. The system of claim 5, wherein said pump structure is mounted to said housing structure.

7. The system of claim 1 further comprising a pump actuator for actuating said pump structure during a refill mode or a recirculation mode.

8. The system of claim 1, wherein the air-fluid separator structure includes a body of capillary material.

9. The system of claim 8, wherein the air-fluid separator structure includes a filter structure preventing passage of air bubbles through the fitter structure under normal operating, shipping and storage conditions experienced by the system and during the pump mode.

10. A re-circulating fluid delivery system, comprising:

a print cartridge housing structure;

separator means for separating air from fluid and venting air from the housing structure, said separator means disposed in said housing structure;

a fluid plenum in fluid communication with the separating means;

fluid ejecting means for ejecting droplets of fluid mounted to said housing structure and in fluid communication with said plenum;

reservoir means for holding a supply of fluid in said housing structure;

a fluid re-circulation path entirely within said housing structure fluidically coupling said separating means, said fluid plenum and said reservoir means; and

re-circulation means for re-circulating fluid through said re-circulation path during a re-circulation mode, wherein air bubbles may be separated from re-circulated fluid and vented from the housing structure.

11. The system of claim 10, wherein said fluid re-circulation path has disposed therein at least one check valve means permitting fluid flow in a re-circulation direction.

12. The system of claim 10, wherein said re-circulation means includes a pump structure mounted to said housing structure.

13. The system of claim 10 further comprising a supply means for holding a supply of fluid external to said housing structure and an interconnect means for establishing a fluid connection between the supply means and said reservoir means.

14. The system of claim 13, wherein said fluid supply and said housing structure are intermittently connectable during a refill mode, and are disconnected during printing operations performed by said fluid ejecting means.

15. The system of claim 10 further comprising actuator means for actuating said re-circulation means during a refill mode or a recirculation mode.

16. The system of claim 10, wherein the separator means includes a body of capillary material.

17. A re-circulating fluid delivery system, comprising:

a print cartridge housing structure;

an air-fluid separator structure in said housing structure;

an air vent region in communication with the separator structure;

a fluid plenum disposed in said housing structure in fluid communication with said separator structure;

a free fluid reservoir disposed in said housing structure;

a fluid re-circulation path entirely within said housing structure, the fluid recirculation path fluidically coupling said separator structure, said fluid plenum and said free fluid reservoir;

a pump structure for re-circulating fluid through said re-circulation path during a pump mode;

a fluid supply external to said housing structure; and

a fluid interconnect structure for removable connection of the fluid supply to the free fluid reservoir to provide replenishment of fluid in the free fluid reservoir during fluid recirculation, wherein said fluid supply and said print cartridge are intermittently connectable during a refill mode, and are disconnected during printing operations performed by said print cartridge.

18. The system of claim 17, wherein said fluid re-circulation path has disposed therein at least one check valve permitting fluid flow in a re-circulation direction.

19. The system of claim 17, wherein;

said pump structure is disposed on or in said housing structure.

20. The system of claim 17, further including a printhead in fluid communication with said plenum.

21. A re-circulating fluid delivery system, comprising:

a print cartridge housing structure;

an air-fluid separator structure in said housing structure;

an air vent region in communication with the separator structure;

a fluid plenum disposed in said housing structure in fluid communication with said separator structure;

a free fluid reservoir disposed in said housing structure;

a fluid re-circulation path entirely within said housing structure, the fluid recirculation path fluidically coupling said separator structure, said fluid plenum and said free fluid reservoir;

a pump structure for re-circulating fluid through said re-circulation path during a pump mode;

a fluid supply external to said housing structure;

a fluid interconnect structure for removable connection of the fluid supply to the free fluid reservoir to provide replenishment of fluid in the free fluid reservoir during fluid recirculation; and

a pump actuator for actuating said pump structure during a refill mode or a recirculation mode.

22. A re-circulating fluid delivery system, comprising:

a print cartridge housing structure;

an air-fluid separator structure in said housing structure, wherein the air-fluid separator structure includes a body of capillary material;

an air vent region in communication with the separator structure;

a fluid plenum disposed in said housing structure in fluid communication with said separator structure;

a free fluid reservoir disposed in said housing structure;

a fluid re-circulation path entirely within said housing structure, the fluid recirculation path fluidically coupling said separator structure, said fluid plenum and said free fluid reservoir;

- a pump structure for re-circulating fluid through said re-circulation path during a pump mode;
- a fluid supply external to said housing structure; and
- a fluid interconnect structure for removable connection of the fluid supply to the free fluid reservoir to provide replenishment of fluid in the free fluid reservoir during fluid recirculation.

23. The system of claim **22,** wherein the air-fluid separator structure includes a filter preventing passage of air bubbles through the filter structure under normal operating, shipping and storage conditions experienced by the system.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,955,425 B2
APPLICATION NO. : 10/133708
DATED : October 18, 2005
INVENTOR(S) : Ashley E. Childs et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

IN THE CLAIMS

Claim 9, Column 7, line 23, delete “fitter” and insert therefor --filter--

Signed and Sealed this

Twenty-sixth Day of June, 2007

JON W. DUDAS

Director of the United States Patent and Trademark Office